

What is Claimed is:

- 1           1.       An apparatus for generating an output waveform at a desired frequency  
2 comprising:  
3           a plurality of waveform synthesizers each generating an intermediate waveform of an  
4 intermediate frequency and including a maximum sampling rate, wherein said intermediate  
5 frequency is less than said desired frequency and said maximum sampling rate is less than a  
6 minimum sampling frequency required for generation of said output waveform; and  
7           a waveform generator to combine said intermediate waveforms from said waveform  
8 synthesizers to produce said output waveform.
- 1           2.       The apparatus of claim 1, wherein at least said plurality of synthesizers is in the  
2 form of at least one of a field programmable gate array (FPGA) and an application specific  
3 integrated circuit (ASIC).
- 1           3.       The apparatus of claim 1, wherein said waveform synthesizers produce a quantity  
2 of said intermediate waveforms proportional to said minimum sampling frequency divided by said  
3 maximum sampling rate of said synthesizers.
- 1           4.       The apparatus of claim 1, wherein each waveform synthesizer includes:  
2 a phase accumulator to produce a phase value of said intermediate waveform; and  
3 a phase converter to generate intermediate waveform amplitudes in accordance with  
4 phase values produced by said phase accumulator to generate said intermediate waveform.
- 1           5.       The apparatus of claim 4, wherein said intermediate waveform amplitudes  
2 generated by said phase converter are in the form of at least one of sine and cosine values.
- 1           6.       The apparatus of claim 4, wherein each synthesizer further includes:  
2 a modulation module to produce a modulated intermediate waveform;

3            wherein said waveform generator combines said modulated intermediate waveforms from  
4            said waveform synthesizers to produce said output waveform with modulation.

1            7.        The apparatus of claim 6, wherein said modulation module includes:  
2            a phase modulation module to apply a phase offset to said phase value to enable said  
3            phase converter to generate a phase modulated intermediate waveform;  
4            wherein said waveform generator combines said phase modulated intermediate waveforms  
5            from said waveform synthesizers to produce said output waveform with phase modulation.

1            8.        The apparatus of claim 6, wherein said modulation module includes:  
2            a frequency modulation module to apply a frequency offset to said phase value to enable  
3            said phase converter to produce a frequency modulated intermediate waveform;  
4            wherein said waveform generator combines said frequency modulated intermediate  
5            waveforms from said waveform synthesizers to produce said output waveform with frequency  
6            modulation.

1            9.        The apparatus of claim 6, wherein said modulation module includes:  
2            an amplitude modulation module to apply amplitude offsets to said intermediate  
3            waveform amplitudes to produce an amplitude modulated intermediate waveform;  
4            wherein said waveform generator combines said amplitude modulated intermediate  
5            waveforms from said waveform synthesizers to produce said output waveform with amplitude  
6            modulation.

1            10.      The apparatus of claim 4, wherein said waveform generator includes:  
2            a multiplexer to combine said intermediate waveforms from said waveform synthesizers  
3            to produce a digital waveform corresponding to said output waveform; and  
4            a digital-to-analog converter to convert said digital waveform to said output waveform in  
5            analog form including said desired frequency.

1           11.     The apparatus of claim 10, wherein each waveform synthesizer applies a  
2     corresponding phase offset to said phase value to produce said intermediate waveforms  
3     successively shifted in phase relative to each other and collectively encompassing samples of said  
4     output waveform.

1           12.     The apparatus of claim 11, wherein said multiplexer selects and retrieves said  
2     output waveform samples from each successive intermediate waveform in a cyclical fashion to  
3     produce said digital waveform corresponding to said output waveform.

1           13.     A method of generating an output waveform at a desired frequency comprising:

2           (a)     generating a plurality of intermediate waveforms each of an intermediate  
3     frequency, wherein said intermediate waveforms are generated by corresponding waveform  
4     synthesizers including a maximum sampling rate and said intermediate frequency is less than said  
5     desired frequency and said maximum sampling rate is less than a minimum sampling frequency  
6     required for generation of said output waveform; and

7           (b)     combining said intermediate waveforms to produce said output waveform.

1           14.     The method of claim 13, wherein step (a) further includes:

2           (a.1)    generating a quantity of said intermediate waveforms proportional to said  
3     minimum sampling frequency divided by said maximum sampling rate of said synthesizers.

1           15.     The method of claim 13, wherein step (a) further includes:

2           (a.1)    generating each intermediate waveform by producing phase values of said  
3     intermediate waveform and determining intermediate waveform amplitudes in accordance with  
4     said produced phase values.

1           16.     The method of claim 15, wherein step (a.1) further includes:

2           (a.1.1) determining said intermediate waveform amplitudes in the form of at least one of  
3     sine and cosine values.

1           17.     The method of claim 15, wherein step (a.1) further includes:  
2           (a.1.1) generating each intermediate waveform as a modulated waveform; and  
3           step (b) further includes:  
4           (b.1) combining said modulated intermediate waveforms to produce said output  
5 waveform with modulation.

1           18.     The method of claim 17, wherein step (a.1.1) further includes:  
2           (a.1.1.1) applying a phase offset to said phase values to generate each intermediate  
3 waveform as a phase modulated waveform; and  
4           step (b.1) further includes:  
5           (b.1.1) combining said phase modulated intermediate waveforms to produce said output  
6 waveform with phase modulation.

1           19.     The method of claim 17, wherein step (a.1.1) further includes:  
2           (a.1.1.1) applying a frequency offset to said phase values to generate each  
3 intermediate waveform as a frequency modulated waveform; and  
4           step (b.1) further includes:  
5           (b.1.1) combining said frequency modulated intermediate waveforms to produce said  
6 output waveform with frequency modulation.

1           20.     The method of claim 17, wherein step (a.1.1) further includes:  
2           (a.1.1.1) applying amplitude offsets to said intermediate waveform amplitudes to  
3 generate each intermediate waveform as an amplitude modulated waveform; and  
4           step (b.1) further includes:  
5           (b.1.1) combining said amplitude modulated intermediate waveforms to produce said  
6 output waveform with amplitude modulation.

1           21.     The method of claim 15, wherein step (b) further includes:

2           (b.1) combining said intermediate waveforms via a multiplexer to produce a digital  
3 waveform corresponding to said output waveform; and

4           (b.2) converting said digital waveform to said output waveform in analog form  
5 including said desired frequency.

1           22. The method of claim 21, wherein step (a.1) further includes:

2           (a.1.1) applying a corresponding phase offset to said phase values to produce said  
3 intermediate waveforms successively shifted in phase relative to each other and collectively  
4 encompassing samples of said output waveform.

1           23. The method of claim 22, wherein step (b.1) further includes:

2           (b.1.1) selecting and retrieving said output waveform samples from each successive  
3 intermediate waveform in a cyclical fashion to produce said digital waveform corresponding to  
4 said output waveform.